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(71) Applicant *(for all designated States except US)*: BYK GULDEN LOMBERG CHEMISCHE FABRIK GMBH [DE/DE]; Byk–Gulden–Str. 2, D–78467 Konstanz (DE).

(72) Inventors *(for all designated States except CA US)*: FLOCKERZI, Dieter; Ackerweg 26, D–78476 Allensbach (DE). AMSCHLER, Hermann (deceased).

(72) Inventors *(for all designated States except CA US)*: GRUNDLER, Gerhard; Meersburger Str. 4, D–78464 Konstanz (DE). HATZELMANN, Armin; Alter Wall 3, D–78467 Konstanz (DE). BUNDSCHUH, Daniela; Rheingutstrasse 17, D–78462 Konstanz (DE). BEUME, Rolf; Bohlstrasse 13, D–78465 Konstanz (DE). BOSS, Hildegard; Flurweg 3a, D–78464 Konstanz (DE). KLEY, Hans–Peter; Im Weinberg 3b, D–78476 Allensbach (DE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: GUTTERER, Beate [DE/DE]; Allensbacher Strasse 6b, D–78476 Allensbach (DE).

(74) Common Representative: BYK GULDEN LOMBERG CHEMISCHE FABRIK GMBH; Byk–Gulden–Str. 2, D–78467 Konstanz (DE).

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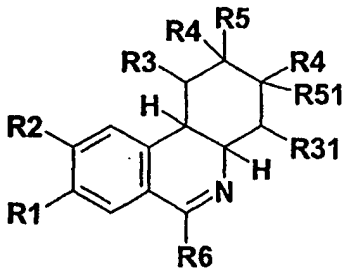

(I)

(57) Abstract

Compounds of formula (I), in which R1, R2, R3, R31, R4, R5, R51 and R6 have the meanings indicated in the description, are novel active bronchial therapeutics.

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POLYSUBSTITUTED 6-PHENYLPHENANTHRIDINES WITH PDE-IV INHIBITING ACTIVITY

Field of application of the invention

The invention relates to novel polysubstituted 6-phenylphenanthridines, which are used in the pharmaceutical industry for the production of medicaments.

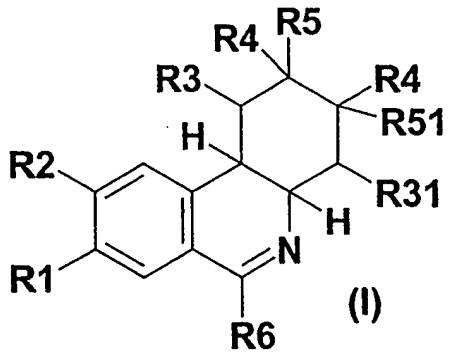
Known technical background

Chem.Ber. **1939**, 72, 675-677, J. Chem. Soc., **1956**, 4280-4283 and J. Chem. Soc.(C), **1971**, 1805 describe the synthesis of 6-phenylphenanthridines. The International Applications WO 97/28131 and WO 97/35854 describe 6-phenyl- and 6-pyridylphenanthridines as PDE4 inhibitors.

Description of the invention

It has now been found that the novel 6-phenylphenanthridines described in greater detail below, which differ from the previously known 6-phenylphenanthridines by a different substitution pattern on the 6-phenyl ring, have surprising and particularly advantageous properties.

The invention thus relates to compounds of the formula I,



(I)

in which

R1 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R2 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

or in which

R1 and R2 together are a 1-2C-alkylenedioxy group,

R3 is hydrogen or 1-4C-alkyl,

R31 is hydrogen or 1-4C-alkyl,

or in which

R3 and R31 together are a 1-4C-alkylene group,

R4 is hydrogen or 1-4C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is a phenyl radical substituted by R7, R19 and R20,

R7 is hydroxyl, halogen, cyano, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, completely or predominantly fluorine-substituted 1-4C-alkoxy, phenyl, phenyl-1-4C-alkyl, C(O)-OR8, C(O)-N(R9)R10, N(R14)R15, $S(O)_2$-R16 or $S(O)_2$-N(R17)R18,

R8 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl,

R9 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl, and

R10 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl, pyridyl, R11-substituted pyridyl, or aryl,

or where R9 and R10, together and including the nitrogen atom to which both are bonded, are a 1-pyrrolidinyl, 1-piperidinyl, 1-piperazinyl, 4-methylpiperazin-1-yl, 1-hexahydroazepinyl or 4-morpholinyl radical,

R11 is halogen, nitro, carboxyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

aryl is phenyl or R12- and/or R13-substituted phenyl, where

R12 is hydroxyl, halogen, 1-4C-alkyl or 1-4C-alkoxy,

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, 1-4C-alkylcarbonylamino, amino, mono- or di-1-4C-alkylamino, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is hydrogen, 1-4C-alkyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R15 is 1-4C-alkyl, 1-4C-alkylcarbonyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R16 is 1-4C-alkyl,

R17 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl,

R18 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl or aryl,

or where R17 and R18, together and including the nitrogen atom to which both are bonded, are a 1-pyrrolidinyl, 1-piperidinyl, 1-piperazinyl, 4-methylpiperazin-1-yl, 1-hexahydroazepinyl or 4-morpholinyl radical,

R19 is hydroxyl, halogen, nitro, cyano, amino, mono- or di-1-4C-alkylamino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, completely or predominantly fluorine-substituted 1-4C-alkoxy, carboxyl, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, 1-4C-alkylcarbonylamino, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl, and

R20 is hydroxyl, halogen, nitro, 1-4C-alkoxy, 1-4C-alkyl or 1-4C-alkylcarbonyloxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 have the same meaning and are selected from the group consisting of trifluoromethyl, nitro, amino, mono- or di-1-4C-alkylamino, 1-4C-alkylcarbonylamino, carboxyl, 1-4C-alkoxycarbonyl, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl and completely or predominantly fluorine-substituted 1-4C-alkoxy,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

1-4C-Alkyl represents a straight-chain or branched alkyl radical having 1 to 4 carbon atoms. Examples which may be mentioned are the butyl, isobutyl, sec-butyl, tert-butyl, propyl, isopropyl and preferably the ethyl and methyl radicals.

1-4C-Alkoxy represents radicals which, in addition to the oxygen atom, contain a straight-chain or branched alkyl radical having 1 to 4 carbon atoms. Examples which may be mentioned are the butoxy, isobutoxy, sec-butoxy, tert-butoxy, propoxy, isopropoxy and preferably the ethoxy and methoxy radicals.

3-7C-Cycloalkoxy represents cyclopropyloxy, cyclobutyloxy, cyclopentyloxy, cyclohexyloxy and cycloheptyloxy, of which cyclopropyloxy, cyclobutyloxy and cyclopentyloxy are preferred.

3-7C-Cycloalkylmethoxy represents cyclopropylmethoxy, cyclobutylmethoxy, cyclopentylmethoxy, cyclohexylmethoxy and cycloheptylmethoxy, of which cyclopropylmethoxy, cyclobutylmethoxy and cyclopentylmethoxy are preferred.

As completely or predominantly fluorine-substituted 1-4C-alkoxy, for example, the 2,2,3,3,3-pentafluoropropoxy, the perfluoroethoxy, the 1,2,2-trifluoroethoxy, in particular the 1,1,2,2-tetrafluoroethoxy, the 2,2,2-trifluoroethoxy, the trifluoromethoxy and preferably the difluoromethoxy radicals may be mentioned. "Predominantly" in this connection means that more than half of the hydrogen atoms are replaced by fluorine atoms.

1-2C-Alkylenedioxy represents, for example, the methylenedioxy [-O-CH_2-O-] and the ethylenedioxy [-O-CH_2-CH_2-O-] radicals.

If R3 and R31 together have the meaning 1-4C-alkylene, the positions 1 and 4 in compounds of the formula I are linked to one another by a 1-4C-alkylene bridge, 1-4C-alkylene representing straight-chain or branched alkylene radicals having 1 to 4 carbon atoms. Examples which may be mentioned are the radicals methylene [$-CH_2-$], ethylene [$-CH_2-CH_2-$], trimethylene [$-CH_2-CH_2-CH_2-$], 1,2-dimethylethylene [$-CH(CH_3)-CH(CH_3)-$] and isopropylidene [$-C(CH_3)_2-$].

If R5 and R51 together are an additional bond, then the carbon atoms in positions 2 and 3 in compounds of the formula I are linked to one another via a double bond.

Halogen within the meaning of the invention is bromine, chlorine or fluorine.

Phenyl-1-4C-alkyl represents one of the abovementioned, phenyl-substituted 1-4C-alkyl radicals. Examples which may be mentioned are the phenethyl and the benzyl radicals.

3-7C-Cycloalkyl represents cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl and cycloheptyl, of which cyclopropyl, cyclobutyl and cyclopentyl are preferred.

3-7C-Cycloalkylmethyl represents a methyl radical which is substituted by one of the abovementioned 3-7C-cycloalkyl radicals. Preferably, the 3-5C-cycloalkylmethyl radicals cyclopropylmethyl, cyclobutylmethyl and cyclopentylmethyl may be mentioned.

1-4C-Alkoxycarbonyl represents a carbonyl group to which one of the abovementioned 1-4C-alkoxy radicals is bonded. Examples which may be mentioned are the methoxycarbonyl [$CH_3O-C(O)-$] and the ethoxycarbonyl [$CH_3CH_2O-C(O)-$] radicals.

1-4C-Alkylcarbonyloxy represents a carbonyloxy group to which one of the abovementioned 1-4C-alkyl radicals is bonded. An example which may be mentioned is the acetoxy radical [$CH_3C(O)-O-$].

In addition to the nitrogen atom, mono- or di-1-4C-alkylamino radicals contain one or two of the abovementioned 1-4C-alkyl radicals. Di-1-4C-alkylamino is preferred and here, in particular, dimethyl-, diethyl- or diisopropylamino.

In addition to the carbonyl group, mono- or di-1-4C-alkylaminocarbonyl radicals contain one of the abovementioned mono- or di-1-4C-alkylamino radicals. Examples which may be mentioned are the N-methyl-, the N,N-dimethyl-, the N-ethyl-, the N-propyl-, the N,N-diethyl- and N-isopropylaminocarbonyl radicals.

As a 1-4C-Alkylcarbonylamino radical, for example, the propionylamino [$C_3H_7C(O)NH$-] and the acetylamino [$CH_3C(O)NH$-] radicals may be mentioned.

Exemplary phenyl radicals R6 substituted by three radicals R7, R19 and R20 which may be mentioned are 2,3,4-trihydroxyphenyl, 3,4,5-trihydroxyphenyl, 2,4,6-trihydroxyphenyl, 3,5-dihydroxy-4-methylphenyl, 2-hydroxy-3,5-diisopropylphenyl, 4-hydroxy-3,5-dimethylphenyl, 2,3,4-trimethoxyphenyl, 3,4,5-trimethoxyphenyl, 3,4,5-triethoxyphenyl, 3-hydroxy-4,5-dimethoxyphenyl, 2-bromo-4,5-dimethoxyphenyl, 3,5-dimethoxy-4-methylphenyl, 4,5-dimethoxy-2-methylphenyl, 2,5-dichloro-3-nitrophenyl, 3,5-dibromo-4-hydroxyphenyl, 3,5-dibromo-2-hydroxyphenyl, 3,5-dibromo-4-methylphenyl, 3,5-dichloro-2-hydroxyphenyl, 3,5-dichloro-2-methoxyphenyl, 3,5-dichloro-4-hydroxyphenyl, 3,5-dichloro-4-methoxyphenyl, 5-bromo-2,4-dihydroxyphenyl, 4-bromo-3,5-dihydroxyphenyl, 4-chloro-3,5-dinitrophenyl, 2-hydroxy-3,5-dinitrophenyl, 4-hydroxy-3,5-dinitrophenyl, 2-methyl-3,5-dinitrophenyl, 2-chloro-4,5-dinitrophenyl, 4-dimethylamino-3,5-dinitrophenyl, 2,4-dichloro-5-sulfamoylphenyl, 4-amino-3,5-dichlorophenyl, 3-amino-2,5-dichlorophenyl, 3,5-diamino-2-methylphenyl, 2,4,6-trimethylphenyl, 4-tert-butyl-2,6-dimethylphenyl, 3,5-di-tert-butyl-4-hydroxyphenyl, 3,5-dimethyl-4-nitrophenyl, 3,5-dimethyl-4-methoxyphenyl, 3-chloro-4-hydroxy-5-methoxyphenyl, 3-carboxy-4-hydroxy-5-methoxyphenyl, 4-carboxy-2,5-dimethylphenyl, 4-carboxy-2,5-dichlorophenyl, 2,3,5-trichlorophenyl, 3,4,5-triacetoxyphenyl and 3-methylsulfonyl-4,5-dimethoxyphenyl.

Exemplary phenyl radicals R6 substituted by two identical radicals R21 and R22 which may be mentioned are bis-2,6-trifluoromethylphenyl, bis-2,5-trifluoromethylphenyl, bis-3,5-trifluoromethylphenyl, bis-4,6-trifluoromethylphenyl, 3,4-dicarboxyphenyl, 3,5-dicarboxyphenyl, 3,5-diacetoxyphenyl, 3,5-diacetamidophenyl, 3,4-diacetamidophenyl, 2,4-dinitrophenyl, 3,4-dinitrophenyl, 3,5-dinitrophenyl, 3,4-diaminophenyl and 3,5-diaminophenyl.

Possible salts for compounds of the formula I -depending on substitution - are all acid addition salts or all salts with bases. Particular mention may be made of the pharmacologically tolerable salts of the inorganic and organic acids and bases customarily used in pharmacy. Those suitable are, on the one hand, water-soluble and water-insoluble acid addition salts with acids such as, for example, hydrochloric acid, hydrobromic acid, phosphoric acid, nitric acid, sulfuric acid, acetic acid, citric acid, D-gluconic acid, benzoic acid, 2-(4-hydroxybenzoyl)benzoic acid, butyric acid, sulfosalicylic acid, maleic acid, lauric acid, malic acid, fumaric acid, succinic acid, oxalic acid, tartaric acid, embonic acid, stearic acid, toluenesulfonic acid, methanesulfonic acid or 3-hydroxy-2-naphthoic acid, it being possible to employ the acids in salt preparation - depending on whether a mono- or polybasic acid is concerned and depending on which salt is desired - in an equimolar quantitative ratio or one differing therefrom.

On the other hand, salts with bases are also suitable. Examples of salts with bases which may be mentioned are alkali metal (lithium, sodium, potassium) or calcium, aluminum, magnesium, titanium, am-

monium, meglumine or guanidinium salts, where here too the bases are employed in salt preparation in an equimolar quantitative ratio or one differing therefrom.

Pharmacologically intolerable salts which can initially be obtained, for example, as process products in the preparation of the compounds according to the invention on an industrial scale are converted into pharmacologically tolerable salts by processes known to the person skilled in the art.

It is known to the person skilled in the art that the compounds according to the invention and their salts, when they are isolated, for example, in crystalline form, can contain various amounts of solvents. The invention therefore also comprises all solvates and in particular all hydrates of the compounds of the formula I, and also all solvates and in particular all hydrates of the salts of the compounds of the formula I.

Compounds of the formula I to be emphasized are those in which

R1 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,

R2 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,

R3 is hydrogen,

R31 is hydrogen,

R4 is hydrogen or 1-2C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is a phenyl radical substituted by R7, R19 and R20,

R7 is hydroxyl, halogen, cyano, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, completely or predominantly fluorine-substituted 1-4C-alkoxy, phenyl, phenyl-1-4C-alkyl, C(O)-OR8, C(O)-N(R9)R10, N(R14)R15, $S(O)_2$-R16 or $S(O)_2$-N(R17)R18,

R8 is hydrogen, 1-4C-alkyl or 3-7C-cycloalkylmethyl,

R9 is hydrogen or 1-4C-alkyl, and

R10 is hydrogen, 1-4C-alkyl, pyridyl, R11-substituted pyridyl, or aryl,

or where R9 and R10, together and including the nitrogen atom to which both are bonded, are a 1-piperidinyl, 1-piperazinyl, 4-methylpiperazin-1-yl or 4-morpholinyl radical,

R11 is halogen, 1-4C-alkoxy, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

aryl is phenyl or R13-substituted phenyl, where

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, amino, mono- or di-1-4C-alkylamino, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is hydrogen or 1-4C-alkyl,

R15 is 1-4C-alkyl, 1-4C-alkylcarbonyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R16 is 1-4C-alkyl,

R17 is hydrogen or 1-4C-alkyl,

R18 is hydrogen, 1-4C-alkyl or aryl,

R19 is hydroxyl, halogen, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, carboxyl, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, 1-4C-alkylcarbonylamino, aminocarbonyl, and

R20 is hydroxyl, halogen, 1-4C-alkoxy, or 1-4C-alkyl,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 have the same meaning and are selected from the group consisting of trifluoromethyl, nitro, amino, 1-4C-alkylcarbonylamino, carboxyl, 1-4C-alkoxycarbonyl and aminocarbonyl,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

Compounds of the formula I particularly to be emphasized are those in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is hydroxyl, halogen, cyano, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, C(O)-OR8, C(O)-N(R9)R10, N(R14)R15, $S(O)_2$-R16 or $S(O)_2$-N(R17)R18,

R8 is hydrogen or 1-4C-alkyl,

R9 is hydrogen, and

R10 is hydrogen, 1-4C-alkyl, pyridyl or aryl,

or where R9 and R10, together and including the nitrogen atom to which both are bonded, are a 1-piperidinyl radical,

aryl is phenyl or R13-substituted phenyl, where

R13 is halogen, nitro, cyano, 1-4C-alkyl or 1-4C-alkoxy,

R14 is hydrogen or 1-4C-alkyl,

R15 is 1-4C-alkyl, 1-4C-alkylcarbonyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R16 is 1-4C-alkyl,

R17 is hydrogen or 1-4C-alkyl,

R18 is hydrogen, 1-4C-alkyl or aryl,

R19 is hydroxyl, halogen, nitro, 1-4C-alkoxy or 1-4C-alkyl, and

R20 is hydroxyl, halogen, 1-4C-alkoxy or 1-4C-alkyl,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 have the same meaning and are selected from the group consisting of trifluoromethyl, nitro, carboxyl and 1-4C-alkoxycarbonyl,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

Preferred compounds of the formula I are those in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is hydroxyl, 1-4C-alkoxy or $S(O)_2$-R16,

R16 is 1-4C-alkyl,

R19 is hydroxyl or 1-4C-alkoxy,

R20 is hydroxyl or 1-4C-alkoxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 both have the same meaning and are selected from the group consisting of trifluoromethyl and nitro,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

Particularly preferred compounds of the formula I are those in which

R1 is methoxy,

R2 is methoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is methoxy, ethoxy or $S(O)_2$-R16,

R16 is methyl,

R19 is methoxy or ethoxy,

R20 is methoxy or ethoxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 both have the same meaning and are selected from the group consisting of trifluoromethyl and nitro,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

An embodiment of the particularly preferred compounds of the formula I are those in which

R1 is methoxy,

R2 is methoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is methoxy or $S(O)_2$-R16,

R16 is methyl,

R19 is methoxy,

R20 is methoxy,

or in which

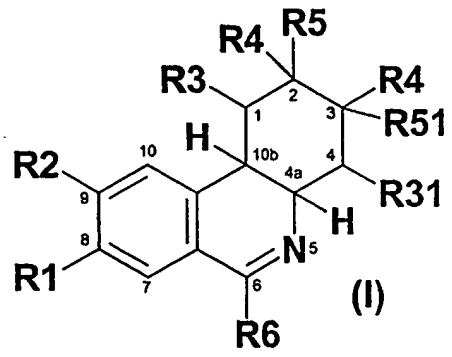
R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 both have the same meaning and are selected from the group consisting of trifluoromethyl and nitro,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

The compounds of the formula I are chiral compounds having chiral centers in positions 4a and 10b and, depending on the meaning of the substituents R3, R31, R4, R5 and R51, further chiral centers in the positions 1, 2, 3 and 4.

Numbering:

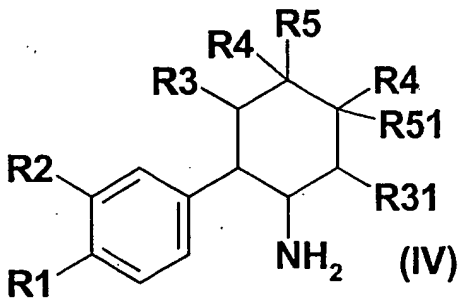


(I)

The invention therefore comprises all conceivable pure diastereomers and pure enantiomers and their mixtures in any mixing ratio, including the racemates. The compounds of the formula I are preferred in which the hydrogen atoms in positions 4a and 10b are cis to one another. The pure cis enantiomers are particularly preferred.

In this connection, particularly preferred compounds of the formula I are those in which positions 4a and 10b have the same absolute configuration as the compound (-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene employable as a starting compound and having the optical rotation $[\alpha]_D^{20}$ = -58.5° (c = 1, ethanol).

The enantiomers can be separated in a manner known per se (for example by preparation and separation of appropriate diastereoisomeric compounds). Preferably, an enantiomer separation is carried out at the stage of the starting compounds of the formula IV

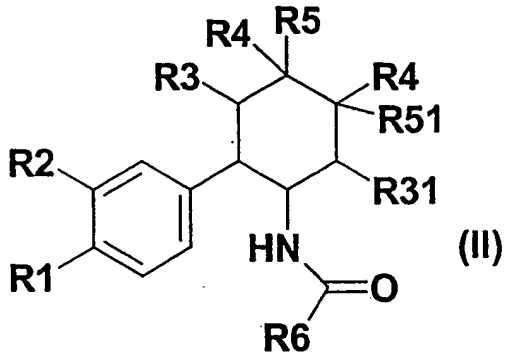


(IV)

for example by means of salt formation of the racemic compounds of the formula IV with optically active carboxylic acids. Examples which may be mentioned in this connection are the enantiomeric forms of mandelic acid, tartaric acid, O,O'-dibenzoyltartaric acid, camphoric acid, quinic acid, glutamic acid, malic acid, camphorsulfonic acid, 3-bromocamphorsulfonic acid, α-methoxyphenylacetic acid, α-methoxy-α-trifluoromethylphenylacetic acid and 2-phenylpropionic acid. Alternatively, enantiomerically pure starting compounds of the formula IV can also be prepared via asymmetric syntheses.

The preparation of the compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51 and R6 have the meanings indicated above and their salts can be carried out, for example, by the process described below in greater detail.

The process comprises cyclocondensing compounds of the formula II



(II)

in which R1, R2, R3, R31, R4, R5, R51 and R6 have the meanings indicated above, and, optionally, then converting the compounds of the formula I obtained into their salts, or, optionally, then converting salts of the compounds of the formula I obtained into the free compounds.

Compounds of the formula I obtained can be converted, optionally, into further compounds of the formula I by derivatization.

For example, from compounds of the formula I in which R6 is a phenyl radical substituted by R7, R19 and R20 and

a) R7 and/or R13 and/or R19 are an ester group, the corresponding acids can be obtained by acidic or alkaline hydrolysis, or the corresponding amides can be prepared by reaction with suitably substituted amines;

b) R13 and/or R20 are a 1-4C-alkylcarbonyloxy group, the corresponding hydroxyl compounds can be obtained by acidic or alkaline hydrolysis;

c) R7 and/or R13 and/or R19 are a nitro group, the corresponding amino compounds, which, for their part, can again be further derivatized, can be obtained by selective catalytic hydrogenation.

Correspondingly, from compounds of the formula I in which R6 is an R21- and R22-substituted phenyl radical and

d) R21 and R22 are an ester group, the corresponding acid can be obtained by acidic and alkaline hydrolysis, or the corresponding amides can be prepared by reaction with suitably substituted amines;

e) R21 and R22 are a nitro group, the corresponding amino compounds which, for their part, can again be further derivatized, can be obtained by selective catalytic hydrogenation.

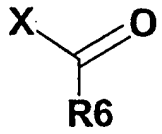
The methods mentioned under a), b), c), d) and e) are expediently carried out analogously to the methods known to the person skilled in the art.

In addition, the compounds of the formula I can be converted, optionally, into their N-oxides, for example with the aid of hydrogen peroxide in methanol or with the aid of m-chloroperoxybenzoic acid in dichloromethane. The person skilled in the art is familiar on the basis of his/her expert knowledge with the reaction conditions which are specifically necessary for carrying out the N-oxidation.

The cyclocondensation is carried out in a manner known per se to the person skilled in the art, according to Bischler-Napieralski (e.g. as described in J. Chem. Soc., **1956**, 4280-4282) in the presence of a suitable condensing agent, such as, for example, polyphosphoric acid, phosphorus pentachloride, phosphorus pentoxide or preferably phosphorus oxychloride, in a suitable inert solvent, e.g. in a chlori-

nated hydrocarbon such as chloroform, or in a cyclic hydrocarbon such as toluene or xylene, or another inert solvent such as acetonitrile, or without further solvent using an excess of condensing agent, preferably at elevated temperature, in particular at the boiling temperature of the solvent or condensing agent used.

Compounds of the formula II in which R1, R2, R3, R31, R4, R5, R51 and R6 have the meanings indicated above are accessible from the corresponding compounds of the formula IV, in which R1, R2, R3, R31, R4, R5 and R51 have the meanings indicated above, by reaction with compounds of the formula III,

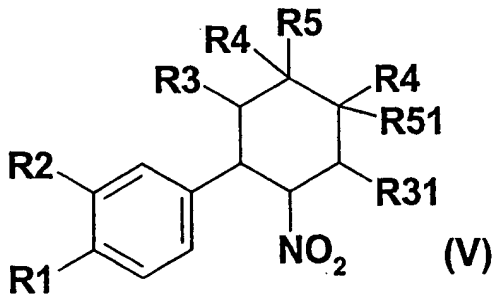


(III)

in which R6 has the meanings indicated above and X represents a suitable leaving group, preferably a chlorine atom. For example, the acylation or benzoylation is carried out as described in the following examples or as in J. Chem. Soc. (C), **1971**, 1805-1808.

Compounds of the formula III and compounds of the formula IV are either known or can be prepared in a known manner.

The compounds of the formula IV can be prepared, for example, from compounds of the formula V,



(V)

in which R1, R2, R3, R31, R4, R5 and R51 have the abovementioned meanings, by reduction of the nitro group.

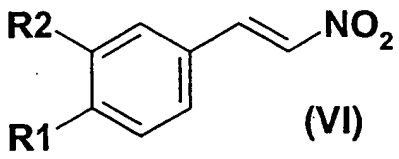
The reduction is carried out in a manner known to the person skilled in the art, for example as described in J. Org. Chem. **1962**, 27, 4426 or as described in the following examples.

The reduction can be carried out, for example, by catalytic hydrogenation, e.g. in the presence of Raney nickel, in a lower alcohol such as methanol or ethanol at room temperature and under normal or elevated pressure. Optionally, a catalytic amount of an acid, such as, for example, hydrochloric acid, can be added to the solvent. Preferably, however, the reduction is carried out using metals such as zinc or iron with organic acids such as acetic acid or mineral acids such as hydrochloric acid.

The compounds of the formula IV in which R1, R2, R3, R31 and R4 have the meanings indicated above and R5 and R51 together represent an additional bond can be prepared from the corresponding compounds of the formula V by selective reduction of the nitro group in a manner known to the person skilled in the art, for example in the presence of Raney nickel in a lower alcohol as solvent using hydrazine hydrate as a hydrogen donor.

The compounds of the formula V, in which R1, R2, R3, R31 and R4 have the meanings indicated above and R5 and R51 are hydrogen, are either known or can be prepared from corresponding compounds of the formula V in which R5 and R51 together are an additional bond. The reaction can be carried out in a manner known to the person skilled in the art, preferably by hydrogenation in the presence of a catalyst, such as, for example, palladium on active carbon, e.g. as described in J. Chem. Soc. (C), **1971**, 1805-1808.

The compounds of the formula V, in which R5 and R51 together are an additional bond, are either known or can be obtained by the reaction of compounds of the formula VI,



(VI)

in which R1 and R2 have the meanings mentioned above, with compounds of the formula VII,

R3-CH=C(R4)-C(R4)=CH-R31 (VII)

in which R3, R31 and R4 have the meanings mentioned above.

Compounds of the formula V, in which R5 and R51 together represent an additional bond and R3 and R31 together are a 1-4C-alkylene group can, for example, be obtained by reaction of cyclic compounds of the formula VII, in which R4 has the above-mentioned meanings and R3 and R31 together are a 1-4C-alkylene group [for example cyclohexa-1,3-dien, 2,3-dimethylcyclohexa-1,3-dien, cyclohepta-1,3-

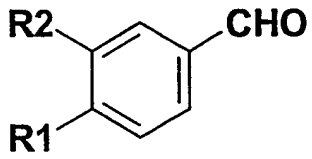
dien, 2,3-dimethylcyclohepta-1,3-dien or cycloocta-1,3-dien] with compounds of the formula VI, in which R1 and R2 have the above-mentioned meanings.

The cycloaddition is in this case carried out in a manner known to the person skilled in the art according to Diels-Alder, e.g. as described in J. Amer. Chem. Soc. **1957**, 79, 6559 or in J. Org. Chem. **1952**, 17, 581 or as described in the following examples.

Compounds of the formula V obtained in the cycloaddition, in which the phenyl ring and the nitro group are trans to one another, can be converted in a manner known to the person skilled in the art into the corresponding cis compounds, e.g. as described in J. Amer. Chem. Soc. **1957**, 79, 6559 or as described in the following examples.

The compounds of the formulae VI and VII are either known or can be prepared in a known manner. The compounds of the formula VI can be prepared, for example, in a manner known to the person skilled in the art from corresponding compounds of the formula VIII as described, for example, in J. Chem. Soc. **1951**, 2524 or in J. Org. Chem. **1944**, 9, 170 or as described in the following examples.

The compounds of the formula VIII,



(VIII)

in which R1 and R2 have the meanings indicated above, are either known or can be prepared in a manner known to the person skilled in the art, as described, for example, in Ber. Dtsch. Chem. Ges. **1925**, 58, 203.

It is moreover known to the person skilled in the art that if there are a number of reactive centers on a starting or intermediate compound it may be necessary to block one or more reactive centers temporarily by protective groups in order to allow a reaction to proceed specifically at the desired reaction center. A detailed description for the use of a large number of proven protective groups is found, for example, in T.W. Greene, Protective Groups in Organic Synthesis, John Wiley & Sons, 1991.

The isolation and purification of the substances according to the invention is carried out in a manner known per se, e.g. by distilling off the solvent in vacuo and recrystallizing the resulting residue from a suitable solvent or subjecting it to one of the customary purification methods, such as, for example, column chromatography on suitable support material.

Salts are obtained by dissolving the free compound in a suitable solvent (e.g. a ketone, such as acetone, methyl ethyl ketone or methyl isobutyl ketone, an ether, such as diethyl ether, tetradhyrofuran or dioxane, a chlorinated hydrocarbon, such as methylene chloride or chloroform, or a low molecular weight aliphatic alcohol such as ethanol or isopropanol) which contains the desired acid or base, or to which the desired acid or base is then added. The salts are obtained by filtering, reprecipitating, precipitating with a nonsolvent for the addition salt or by evaporating the solvent. Salts obtained can be converted by alkalization or by acidification into the free compounds, which in turn can be converted into salts. In this way, pharmacologically intolerable salts can be converted into pharmacologically tolerable salts.

The following examples serve to illustrate the invention further without restricting it. Likewise, further compounds of the formula I, whose preparation is not explicitly described, can be prepared in an analogous manner or in a manner familiar per se to the person skilled in the art using customary process techniques.

In the examples, m.p stands for melting point, h for hour(s), RT for room temperature, EF for empirical formula, MW for molecular weight, calc. for calculated, fnd. for found. The compounds mentioned in the examples and their salts are a preferred subject of the invention.

Examples

1. **(-)-cis-8,9-Dimethoxy-6-(3,4-dinitrophenyl)-1,2,3,4,4a,10b-hexahydrophenanthridine**

7.5 g of (-)-cis-N-[2-(3,4-dimethoxyphenyl)cyclohexyl]-3,4-dinitrobenzamide (compound A1) are dissolved in 120 ml of acetonitrile or toluene and 3.5 ml of phosphorus oxychloride and the solution is stirred overnight at 80°C. The reaction mixture is concentrated under reduced pressure and the residue is extracted with satd. sodium hydrogencarbonate solution and ethyl acetate. The organic phases are dried using sodium sulfate and concentrated. The residue is recrystallized from ethyl acetate.
M.p.: 162-165°C

EF: $C_{21}H_{21}N_3O_6$; MW: 411.42

Elemental analysis: calc.: C 61.30 H 5.26 N 10.21
fnd. : C 61.44 H 5.16 N 10.04

Optical Rotation: $[\alpha]_D^{20}$ = -181.8° (c=0.2, DMF)

Starting from the starting compounds described below, the following are obtained by the procedure according to Example 1:

2. **(-)-cis-6-(Bis-3,5-trifluoromethylphenyl)-8,9-dimethoxy-1,2,3,4,4a,10b-hexahydrophenanthridine**

EF: $C_{23}H_{21}F_6NO_2$; MW: 457.42

Elemental analysis: calc.: C 60.39 H 4.63 N 3.06 F 24.92
fnd. : C 60.38 H 4.85 N 3.04 F 23.86

Optical Rotation: $[\alpha]_D^{20}$ = -151.6° (c=0.2, ethanol)

3. **(-)-cis-8,9-Dimethoxy-6-(3,5-dinitrophenyl)-1,2,3,4,4a,10b-hexahydrophenanthridine**

EF: $C_{21}H_{21}N_3O_6$; MW: 411.42

^{1}H-NMR (200 MHz, DMSO-d_6): 1.2-1.95 ppm (m, 7H), 2.09-2.27 ppm (m, 1H), 2.68-2.87 ppm (m, 1H), 3.58-3.7 ppm (m, 1H), 3.62 ppm (s, 3H), 3.86 ppm (s, 3H), 6.77 ppm (s, 1H), 7.06 ppm (s, 1H), 8.67-8.69 ppm (m, 2H), 8.92-8.95 ppm (m, 1H).

Optical Rotation: $[\alpha]_D^{20}$ = -255° (c=0.2, ethanol)

4. **(-)-cis-8,9-Dimethoxy-6-(3,4,5-trimethoxyphenyl)-1,2,3,4,4a,10b-hexahydrophenanthridine**

EF: $C_{24}H_{29}NO_5$; MW: 411.50

Elemental analysis × 0.19 H_2O: calc.: C 69.47 H 7.14 N 3.38

fnd. : C 69.27 H 7.36 N 3.58

Optical Rotation: $[\alpha]_D^{20}$ = -136.8° (c=0.2, ethanol)

5. **(-)-cis-6-(3-Methanesulfonyl-4,5-dimethoxyphenyl)-8,9-dimethoxy-1,2,3,4,4a,10b-hexahydrophenanthridine**

EF: $C_{24}H_{29}NO_6S$; MW: 459.57

^{1}H-NMR (200 MHz, DMSO-d_6): 1.15-1.85 ppm (m, 7H), 2.17-2.24 ppm (m, 1H), 2.61-2.79 ppm (m, 1H), 3.31 ppm (s, 3H), 3.51-3.61 ppm (m, 1H), 3.65 ppm (s, 3H), 3.85 ppm (s, 3H), 3.93 ppm (s, 3H), 3.97 ppm (s, 3H), 6.8 ppm (s, 1H), 7.01 ppm (s, 1H), 7.57 ppm (s, 2H).

Optical Rotation: $[\alpha]_D^{20}$ = -153.2° (c=0.2, ethanol)

6. **(-)-cis-8,9-Dimethoxy-6-(3,4,5-triethoxyphenyl) -1,2,3,4,4a,10b-hexahydrophenanthridine**

EF: $C_{27}H_{35}NO_5$; MW: 453.58

Elemental analysis: calc.: C 71.50 H 7.78 N 3.09

fnd.: C 71.35 H 8.06 N 3.12

Optical Rotation: $[\alpha]_D^{20}$ = -76.8° (c=0.2, ethanol)

Starting compounds

A1. **(-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl]-3,4-dinitrobenzamide**

5.0 g of (-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene (compound B2) are dissolved in 40 ml of methylene chloride and 5.0 ml of triethylamine. A solution of 6.5 g of 3,4-dinitrobenzoyl chloride in 40 ml of methylene chloride is added dropwise at RT and the mixture is extracted with water, 2N hydrochloric acid, satd. sodium hydrogencarbonate solution and water again after stirring overnight. The organic phase is dried using sodium sulfate and concentrated. 8.1 g of the title compound are obtained as a solidified oil.

Optical Rotation: $[\alpha]_D^{20}$ = -105.4° (c=0.2, ethanol)

Starting from the starting compounds described below, the following are obtained by the procedure according to Example A1:

A2. **(-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl]-3,5-bistrifluoromethylbenzamide**

solidifying oil
Optical Rotation: $[\alpha]_D^{20}$ = -80.5° (c=0.2, ethanol)

A3. **(-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl]-3,5-dinitrobenzamide**

solidifying oil
Optical Rotation: $[\alpha]_D^{20}$ = -104.9° (c=0.2, ethanol)

A4. **(-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl]-3,4,5-trimethoxybenzamide**

oil
Optical Rotation: $[\alpha]_D^{20}$ = -110.4° (c=0.2, ethanol)

A5. **(-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl](3-methanesulfonyl-4,5-dimethoxy)benzamide**

solidifying oil
Optical Rotation: $[\alpha]_D^{20}$ = -114° (c=0.2, ethanol)

A6. **(-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl]-3,4,5-triethoxybenzamide**

solidifying oil
Optical Rotation: $[\alpha]_D^{20}$ = -96.5° (c=0.2, ethanol)

B1 **(+/-)-cis-1,2-Dimethoxy-4-(2-aminocyclohexyl)benzene**

125 g of (+/-)-cis-1,2-dimethoxy-4-(2-nitrocyclohexyl)benzene and 120 g of zinc powder or granules are suspended in 1300 ml of ethanol. 220 ml of acetic acid are added dropwise at boiling heat. The precipitate is filtered off with suction and washed with ethanol, and the filtrate is concentrated under re-

duced pressure. The residue is taken up in hydrochloric acid and extracted with toluene. The aqueous phase is rendered alkaline using 50% strength sodium hydroxide solution, the precipitate is filtered off with suction and the filtrate is extracted with toluene. The organic phase is dried using sodium sulfate and concentrated. 98 g of the title compound are obtained as a crystallizing oil.

Alternatively:

8.5 g of (+/-)-cis-1,2-dimethoxy-4-(2-nitrocyclohexyl)benzene are dissolved in 400 ml of methanol and treated at RT with 7 ml of hydrazine hydrate and 2.5 g of Raney nickel in portions in the course of 8 h. After stirring overnight at RT, the reaction mixture is filtered, the filtrate is concentrated and the residue is chromatographed on silica gel using a mixture of toluene/ethyl acetate/triethylamine = 4/2/0.5. The title compound is obtained as an oil.

B2. (-)-cis-1,2-Dimethoxy-4-(2-aminocyclohexyl)benzene

12.0 g of (+/-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene and 6.2 g of (-)-mandelic acid are dissolved in 420 ml of dioxane and 60 ml of tetrahydrofuran and the solution is stirred overnight at RT. The solid is filtered off with suction, dried, treated with 100 ml of saturated sodium hydrogencarbonate solution and extracted with ethyl acetate. The organic phase is dried using sodium sulphate and concentrated under reduced pressure. 4.8 g of the title compound are obtained of m.p.: 80-81.5°C.
Optical rotation: $[\alpha]_D^{20}$ = -58.5°C (c = 1, ethanol).

C1. (+/-)-cis-1,2-Dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene

10.0 g of (+/-)-trans-1,2-dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene and 20.0 g of potassium hydroxide are dissolved in 150 ml of ethanol and 35 ml of dimethylformamide. A solution of 17.5 ml of conc. sulfuric acid in 60 ml of ethanol is then added dropwise such that the internal temperature does not exceed 4°C. After stirring for 1 h, the mixture is added to 1 l of ice water, the precipitate is filtered off with suction, washed with water and dried, and the crude product is recrystallized from ethanol. 8.6 g of the title compound of m.p. 82.5-84°C are obtained.

C2. (+/-)-cis-1,2-Dimethoxy-4-(2-nitrocyclohexyl)benzene

8.4 g of (+/-)-cis-1,2-dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene are dissolved in 450 ml of methanol, treated with 2 ml of conc. hydrochloric acid and hydrogenated after addition of 500 mg of 10% strength Pd/C. The reaction mixture is filtered and the filtrate is concentrated. M.p.: 84-86.5°C.

D1. (+/-)-trans-1,2-Dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene

50.0 g of 3,4-dimethoxy-ω-nitrostyrene and 1.0 g (9.1 mmol) of hydroquinone are suspended in 200 ml of abs. toluene and treated at -70°C with 55.0 g (1.02 mol) of liquid 1,3-butadiene. The mixture is stirred at 160°C for 6 days in an autoclave and then cooled. Some of the solvent is removed on a rotary evaporator, and the resulting precipitate is filtered off with suction and recrystallized in ethanol. M.p.: 113.5-115.5°C.

E1. 3,4-Dimethoxy-ω-nitrostyrene

207.0 g of 3,4-dimethoxybenzaldehyde, 100.0 g of ammonium acetate and 125 ml of nitromethane are heated to boiling for 3-4 h in 1.0 l of glacial acetic acid. After cooling in an ice bath, the precipitate is filtered off with suction, rinsed with glacial acetic acid and petroleum ether and dried. M.p.: 140-141°C. Yield: 179.0 g.

Commercial applicability

The compounds according to the invention have valuable pharmacological properties which make them commercially utilizable. As selective cyclic nucleotide phosphodiesterase (PDE) inhibitors (namely of type 4), they are suitable on the one hand as bronchial therapeutics (for the treatment of airway obstructions on account of their dilating but also on account of their respiratory rate- or respiratory drive-increasing action) and for the elimination of erectile dysfunction on account of the vasodilating action, but on the other hand especially for the treatment of disorders, in particular of inflammatory nature, e.g. of the airways (asthma prophylaxis), of the skin, of the central nervous system, of the intestine, of the eyes and of the joints, which are mediated by mediators such as histamine, PAF (platelet-activating factor), arachidonic acid derivatives such as leukotrienes and prostaglandins, cytokines, interleukins, chemokines, alpha-, beta- and gamma-interferon, tumor necrosis factor (TNF) or oxygen radicals and proteases. The compounds according to the invention are distinguished here by low toxicity, good enteral absorption (high bioavailability), a large therapeutic breadth and the absence of significant side-effects.

On account of their PDE-inhibiting properties, the compounds according to the invention can be employed in human and veterinary medicine and therapeutics, where they can be used, for example, for the treatment and prophylaxis of the following illnesses: acute and chronic (in particular inflammatory and allergen-induced) airway disorders of various origins (bronchitis, allergic bronchitis, bronchial asthma, emphysema, COPD); dermatoses (especially of proliferative, inflammatory and allergic type) such as, for example, psoriasis (vulgaris), toxic and allergic contact eczema, atopic eczema, seborrheic eczema, lichen simplex, sunburn, pruritus in the anogenital area, alopecia areata, hypertrophic scars, discoid lupus erythematosus, follicular and wide-area pyodermias, endogenous and exogenous acne, acne rosacea and other proliferative, inflammatory and allergic skin disorders; disorders which are based on an excessive release of TNF and leukotrienes, e.g. disorders of the arthritis type (rheumatoid arthritis, rheumatoid spondylitis, osteoarthritis and other arthritic conditions), disorders of the immune system (AIDS, multiple sclerosis), graft-versus-host reactions, transplant rejection reactions, symptoms of shock [septic shock, endotoxin shock, gram-negative sepsis, toxic shock syndrome and ARDS (adult respiratory distress syndrome)], and generalized inflammations in the gastrointestinal area (Crohn's disease and ulcerative colitis); disorders which are based on allergic and/or chronic, faulty immunological reactions in the area of the upper airways (pharynx, nose) and the adjacent regions (paranasal sinuses, eyes), such as, for example, allergic rhinitis/sinusitis, chronic rhinitis/sinusitis, allergic conjunctivitis and nasal polyps; but also disorders of the heart which can be treated by PDE inhibitors, such as, for example, cardiac insufficiency, or disorders which can be treated on account of the tissue-relaxant action of the PDE inhibitors, such as, for example, erectile dysfunction or colics of the kidneys and the ureters in connection with kidney stones. In addition, the compounds according to the invention can be

employed for the treatment of diabetes insipidus and disorders in connection with disturbances of brain metabolism, such as, for example, cerebral senility, senile dementia (Alzheimer's dementia), multiinfarct dementia or alternatively disorders of the CNS, such as, for example, depressions or arteriosclerotic dementia.

A further subject of the invention is a process for the treatment of mammals, including man, which are suffering from one of the abovementioned illnesses. The process comprises administering to the sick mammal a therapeutically efficacious and pharmacologically tolerable amount of one or more of the compounds according to the invention.

The invention further relates to the compounds according to the invention for use in the treatment of mammals, including man, which are suffering from one of the abovementioned illnesses. The process comprises administering to the sick mammal a therapeutically efficacious and pharmacologically tolerable amount of one or more of the compounds according to the invention.

The invention further relates to the compounds according to the invention for use in the treatment and/or prophylaxis of illnesses, in particular the illnesses mentioned.

The invention likewise relates to the use of the compounds according to the invention for the production of medicaments which are employed for the treatment and/or prophylaxis of the illnesses mentioned.

Medicaments for the treatment and/or prophylaxis of the illnesses mentioned, which contain one or more of the compounds according to the invention, are furthermore a subject of the invention.

A further subject of the invention is a commercial product, consisting of a customary secondary pack, a primary pack containing the medicament (for example an ampoule or a blister pack) and, optionally, a pack insert, the medicament exhibiting antagonistic action against cyclic nucleotide phosphodiesterases of type 4 (PDE4) and leading to the attenuation of the symptoms of illnesses which are connected with cyclic nucleotide phosphodiesterases of type 4, and the suitability of the medicament for the prophylaxis or treatment of illnesses which are connected with cyclic nucleotide phosphodiesterases of type 4 being indicated on the secondary pack and/or on the pack insert of the commercial product, and the medicament containing one or more compounds of the formula I according to the invention. The secondary pack, the primary pack containing the medicament and the pack insert otherwise comply with what would be regarded as standard to the person skilled in the art for medicaments of this type.

The medicaments are prepared by processes which are known per se and familiar to the person skilled in the art. As medicaments, the compounds according to the invention (= active compounds) are either employed as such, or preferably in combination with suitable pharmaceutical excipients, e.g. in the form

of tablets, coated tablets, capsules, suppositories, patches, emulsions, suspensions, gels or solutions, the active compound content advantageously being between 0.1 and 95%.

The person skilled in the art is familiar on the basis of his/her expert knowledge with the excipients which are suitable for the desired pharmaceutical formulations. In addition to solvents, gel-forming agents, ointment bases and other active compound vehicles, it is possible to use, for example, antioxidants, dispersants, emulsifiers, preservatives, solubilizers or permeation promoters.

For the treatment of disorders of the respiratory tract, the compounds according to the invention are preferably also administered by inhalation. For this, these are either administered directly as a powder (preferably in micronized form) or by nebulization of solutions or suspensions which contain them. With respect to the preparations and administration forms, reference is made, for example, to the details in European Patent 163 965.

For the treatment of dermatoses, the compounds according to the invention are in particular used in the form of those medicaments which are suitable for topical application. For the production of the medicaments, the compounds according to the invention (= active compounds) are preferably mixed with suitable pharmaceutical excipients and further processed to give suitable pharmaceutical formulations. Suitable pharmaceutical formulations which may be mentioned are, for example, powders, emulsions, suspensions, sprays, oils, ointments, fatty ointments, creams, pastes, gels or solutions.

The medicaments according to the invention are prepared by processes known per se. Dosage of the active compounds takes place in the order of magnitude customary for PDE inhibitors. Thus topical application forms (such as, for example, ointments) for the treatment of dermatoses contain the active compounds in a concentration of, for example, 0.1-99%. The dose for administration by inhalation is customarily between 0.1 and 3 mg per day. The customary dose in the case of systemic therapy (p.o. or i.v.) is between 0.03 and 3 mg per kilogram per day.

Biological investigations

In the investigation of PDE4 inhibition at the cellular level, the activation of inflammatory cells has particular importance. As an example, the FMLP (N-formyl-methionyl-leucyl-phenylalanine)-induced superoxide production of neutrophilic granulocytes may be mentioned, which can be measured as luminol-potentiated chemoluminescence [McPhail LC, Strum SL, Leone PA and Sozzani S, The neutrophil respiratory burst mechanism. In "Immunology Series" **1992**, 57, 47-76; ed. Coffey RG (Marcel Decker, Inc. New York-Basle-Hong Kong)].

Substances which inhibit chemoluminescence and cytokine secretion and the secretion of inflammatory mediators on inflammatory cells, in particular neutrophilic and eosinophilic granulocytes, T lymphocytes, monocytes and macrophages, are those which inhibit PDE4. This isoenzyme of the phosphodiesterase families is particularly represented in granulocytes. Its inhibition leads to an increase in the intracellular cyclic AMP concentration and thus to the inhibition of cell activation. PDE4 inhibition by the substances according to the invention is thus a central indicator of the suppression of inflammatory processes (**Glembycz MA**, Could isoenzyme-selective phosphodiesterase inhibitors render bronchodilatory therapy redundant in the treatment of bronchial asthma?. Biochem Pharmacol **1992**, 43, 2041-2051; **Torphy TJ** et al., Phosphodiesterase inhibitors: new opportunities for treatment of asthma. Thorax **1991**, 46, 512-523; **Schudt C** et al., Zardaverine: a cyclic AMP PDE 3/4 inhibitor. In "New Drugs for Asthma Therapy", 379-402, Birkhäuser Verlag Basle 1991; **Schudt C** et al., Influence of selective phosphodiesterase inhibitors on human neutrophil functions and levels of cAMP and Ca; Naunyn-Schmiedebergs Arch Pharmacol **1991**, 344, 682-690; **Tenor H** and **Schudt C**, Analysis of PDE isoenzyme profiles in cells and tissues by pharmacological methods. In "Phosphodiesterase Inhibitors", 21-40, "The Handbook of Immunopharmacology", Academic Press, 1996; **Hatzelmann A** et al., Enzymatic and functional aspects of dual-selective PDE3/4-inhibitors. In "Phosphodiesterase Inhibitors", 147-160. "The Handbook of Immunopharmacology", Academic Press, 1996).

Inhibition of PDE4 activity

Methodology

The activity test was carried out according to the method of Bauer and Schwabe, which was adapted to microtiter plates (Naunyn-Schmiedeberg's Arch. Pharmacol. 1980, 311, 193-198). The PDE reaction takes place in the first step here. In a second step, the resulting 5'-nucleotide is cleaved by a 5'-nucloetidase of the snake venom of Crotalus atrox to the uncharged nucleoside. In the third step, the nucleoside is separated from the remaining charged substrate on ion-exchange columns. The columns are eluted directly into minivials, into which 2 ml of scintillator fluid are additionally added for counting, using 2 ml of 30 mM ammonium formate (pH 6.0).

The inhibitory values determined for the compounds according to the invention [inhibitory concentration as -log IC_{50} (mol/l)] follow from the following Table A, in which the numbers of the compounds correspond to the numbers of the examples.

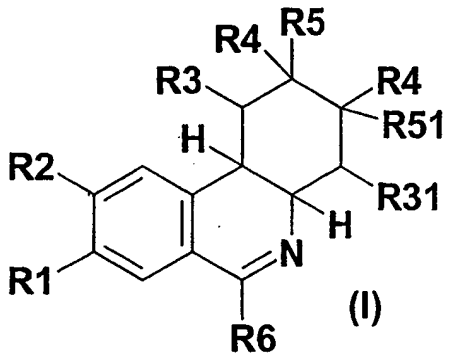
Table A

Inhibition of the PDE4 activity

Compound	-log IC_{50}
1	7.26
2	6.93
3	6.56
4	6.96
5	7.57
6	7.81

Patent claims

1. A compound of the formula I,



in which

R1 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R2 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

or in which

R1 and R2 together are a 1-2C-alkylenedioxy group,

R3 is hydrogen or 1-4C-alkyl,

R31 is hydrogen or 1-4C-alkyl,

or in which

R3 and R31 together are a 1-4C-alkylene group,

R4 is hydrogen or 1-4C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is a phenyl radical substituted by R7, R19 and R20,

R7 is hydroxyl, halogen, cyano, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, completely or predominantly fluorine-substituted 1-4C-alkoxy, phenyl, phenyl-1-4C-alkyl, C(O)-OR8, C(O)-N(R9)R10, N(R14)R15, $S(O)_2$-R16 or $S(O)_2$-N(R17)R18,

R8 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl,

R9 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl, and

R10 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl, pyridyl, R11-substituted pyridyl, or aryl,

or where R9 and R10, together and including the nitrogen atom to which both are bonded, are a 1-pyrrolidinyl, 1-piperidinyl, 1-piperazinyl, 4-methylpiperazin-1-yl, 1-hexahydroazepinyl or 4-morpholinyl radical,

R11 is halogen, nitro, carboxyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

aryl is phenyl or R12- and/or R13-substituted phenyl, where

R12 is hydroxyl, halogen, 1-4C-alkyl or 1-4C-alkoxy,

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, 1-4C-alkylcarbonylamino, amino, mono- or di-1-4C-alkylamino, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is hydrogen, 1-4C-alkyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R15 is 1-4C-alkyl, 1-4C-alkylcarbonyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R16 is 1-4C-alkyl,

R17 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl,

R18 is hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl or aryl,

or where R17 and R18, together and including the nitrogen atom to which both are bonded, are a 1-pyrrolidinyl, 1-piperidinyl, 1-piperazinyl, 4-methylpiperazin-1-yl, 1-hexahydroazepinyl or 4-morpholinyl radical,

R19 is hydroxyl, halogen, nitro, cyano, amino, mono- or di-1-4C-alkylamino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, completely or predominantly fluorine-substituted 1-4C-alkoxy, carboxyl, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, 1-4C-alkylcarbonylamino, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl, and

R20 is hydroxyl, halogen, nitro, 1-4C-alkoxy, 1-4C-alkyl or 1-4C-alkylcarbonyloxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 have the same meaning and are selected from the group consisting of trifluoromethyl, nitro, amino, mono- or di-1-4C-alkylamino, 1-4C-alkylcarbonylamino, carboxyl, 1-4C-alkoxycarbonyl, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl and completely or predominantly fluorine-substituted 1-4C-alkoxy,

or the salts, the N-oxides and the salts of the N-oxides of this compound.

2. A compound of the formula I as claimed in claim 1, in which

R1 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,

R2 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,

R3 is hydrogen,

R31 is hydrogen,

R4 is hydrogen or 1-2C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is a phenyl radical substituted by R7, R19 and R20,

R7 is hydroxyl, halogen, cyano, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, completely or predominantly fluorine-substituted 1-4C-alkoxy, phenyl, phenyl-1-4C-alkyl, C(O)-OR8, C(O)-N(R9)R10, N(R14)R15, $S(O)_2$-R16 or $S(O)_2$-N(R17)R18,

R8 is hydrogen, 1-4C-alkyl or 3-7C-cycloalkylmethyl,

R9 is hydrogen or 1-4C-alkyl, and

R10 is hydrogen, 1-4C-alkyl, pyridyl, R11-substituted pyridyl, or aryl,

or where R9 and R10, together and including the nitrogen atom to which both are bonded, are a 1-piperidinyl, 1-piperazinyl, 4-methylpiperazin-1-yl or 4-morpholinyl radical,

R11 is halogen, 1-4C-alkoxy, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

aryl is phenyl or R13-substituted phenyl, where

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, amino, mono- or di-1-4C-alkylamino, aminocarbonyl, mono- or di-1-4C-alkylaminocarbonyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is hydrogen or 1-4C-alkyl,

R15 is 1-4C-alkyl, 1-4C-alkylcarbonyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R16 is 1-4C-alkyl,

R17 is hydrogen or 1-4C-alkyl,

R18 is hydrogen, 1-4C-alkyl or aryl,

R19 is hydroxyl, halogen, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, carboxyl, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, 1-4C-alkylcarbonylamino, aminocarbonyl, and

R20 is hydroxyl, halogen, 1-4C-alkoxy, or 1-4C-alkyl,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 have the same meaning and are selected from the group consisting of trifluoromethyl, nitro, amino, 1-4C-alkylcarbonylamino, carboxyl, 1-4C-alkoxycarbonyl and aminocarbonyl,

and the salts, the N-oxides and the salts of the N-oxides of this compound.

3. A compound of the formula I as claimed in claim 1, in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is hydroxyl, halogen, cyano, nitro, amino, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, C(O)-OR8, C(O)-N(R9)R10, N(R14)R15, $S(O)_2$-R16 or $S(O)_2$-N(R17)R18,

R8 is hydrogen or 1-4C-alkyl,

R9 is hydrogen, and

R10 is hydrogen, 1-4C-alkyl, pyridyl or aryl,

or where R9 and R10, together and including the nitrogen atom to which both are bonded, are a 1-piperidinyl radical,

aryl is phenyl or R13-substituted phenyl, where

R13 is halogen, nitro, cyano, 1-4C-alkyl or 1-4C-alkoxy,

R14 is hydrogen or 1-4C-alkyl,

R15 is 1-4C-alkyl, 1-4C-alkylcarbonyl, $S(O)_2$-R16 or $S(O)_2$-aryl,

R16 is 1-4C-alkyl,

R17 is hydrogen or 1-4C-alkyl,

R18 is hydrogen, 1-4C-alkyl or aryl,

R19 is hydroxyl, halogen, nitro, 1-4C-alkoxy or 1-4C-alkyl, and

R20 is hydroxyl, halogen, 1-4C-alkoxy or 1-4C-alkyl,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 have the same meaning and are selected from the group consisting of trifluoromethyl, nitro, carboxyl and 1-4C-alkoxycarbonyl,

or the salts, the N-oxides and the salts of the N-oxides of this compound.

4. A compound of the formula I as claimed in claim 1, in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is hydroxyl, 1-4C-alkoxy or $S(O)_2$-R16,

R16 is 1-4C-alkyl,

R19 is hydroxyl or 1-4C-alkoxy,

R20 is hydroxyl or 1-4C-alkoxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 both have the same meaning and are selected from the group consisting of trifluoromethyl and nitro,

and the salts, the N-oxides and the salts of the N-oxides of this compound.

5. A compound of the formula I as claimed in claim 1, in which

R1 is methoxy,

R2 is methoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is methoxy, ethoxy or $S(O)_2$-R16,

R16 is methyl,

R19 is methoxy or ethoxy,

R20 is methoxy or ethoxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 both have the same meaning and are selected from the group consisting of trifluoromethyl and nitro,

and the salts, the N-oxides and the salts of the N-oxides of this compound.

6. A compound of the formula I as claimed in claim 1, in which

R1 is methoxy,

R2 is methoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is an R7-, R19- and R20-substituted phenyl radical,

R7 is methoxy or $S(O)_2$-R16,

R16 is methyl,

R19 is methoxy,

R20 is methoxy,

or in which

R6 is an R21- and R22-substituted phenyl radical and

R21 and R22 both have the same meaning and are selected from the group consisting of trifluoromethyl and nitro,

or the salts, the N-oxides and the salts of the N-oxides of this compound.

7. A compound of the formula I as claimed in one of claims 1, 2, 3, 4, 5 or 6, which has the same absolute configuration in positions 4a and 10b as the compound (-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene having the optical rotation $[\alpha]_D^{20}$ = -58.5° (c = 1, ethanol), which can be employed as a starting material.

8. A compound of the formula I as claimed in claim 1 for use in the treatment of illnesses.

9. A medicament comprising at least one compound of the formula I as claimed in claim 1 together with pharmaceutical excipients and/or vehicles.

10. The use of compounds of the formula I as claimed in claim 1 for the production of medicaments for treating airway disorders.

INTERNATIONAL SEARCH REPORT

Inte .ional Application No
PCT/EP 00/00151

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C07D221/12 A61K31/435 A61P11/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C07D A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 97 35854 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 2 October 1997 (1997-10-02) cited in the application claim 1	1-10
Y	WO 97 28131 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 7 August 1997 (1997-08-07) cited in the application claim 1	1-10
Y	WO 98 21208 A (BYK GULDEN LOMBERG CHEM FAB ;FLOCKERZI DIETER (DE)) 22 May 1998 (1998-05-22) claim 1	1-10

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 May 2000	11/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Steendijk, M

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INTERNATIONAL SEARCH REPORT

Inte. ional Application No
PCT/EP 00/00151

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	DE 39 00 233 A (SANDOZ AG) 20 July 1989 (1989-07-20) page 1	1-10

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